An Analysis of Inductive Coupling and Interference Issues in Digital Wireless Phones: Technically Feasible Solutions

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The purpose of this paper is to clarify issues about inductive coupling and the current sources of interference with hearing aids and CIs from digital mobile phones, and to suggest readily achievable solutions for improving access to the desired speech signal. Discussed is interference from digital radio frequency emissions and non-RF electromagnetic interference (EMI). Please be advised that this analysis is not comprehensive. (SHHH is a consumer organization that lacks resources to conduct sustained research.) Input is welcomed and encouraged; please email dmulvany@usa.net with any suggested feedback or additional information.

Inductive Telecoil Coupling For People with Hearing Loss

The presence of noise affects the speech comprehension of people with partial hearing much more adversely than that of people with normal hearing. People with partial hearing thus require a high signal-to-noise ratio to optimize their speech discrimination. Telecoils help people with hearing loss achieve this high signal-to-noise ratio by coupling the hearing aid (HA) or cochlear implant (CI) inductively with hearing-aid compatible (HAC) phones. Most landline phones are HAC by law.

Telecoils, available in all BTE (behind the ear) and some ITE (in the ear) hearing aids and some cochlear implants, enable the hearing device to process only the sounds that are transmitted through the phone, thus bypassing background noise which in turn optimizes the use of the hearing device. Telecoils also prevent the phenomenon of feedback often caused by placing a hearing aid in microphone mode next to the phone's earpiece; this feedback can adversely affect the functionality of the hearing aid and also disturb bystanders.

The Importance of a Strong Inductive Field in the Telephone

The sensitivity of the telecoil is usually adjustable by the volume control of the hearing aid. Increasing the volume control heightens the telecoil's sensitivity, and creates the perception of louder sound. It also makes the telecoil more sensitive to any nearby electromagnetic interference (EMI). For example, power transformers, fluorescent lighting and trains can cause EMI that can be picked up by telecoils. Lowering the volume on the hearing aid correspondingly reduces the sensitivity of the telecoil to all inductive fields, including environmental EMI. If the telecoil is next to a device (for example, a mobile phone) that transmits desirable sound through an extremely strong inductive field, the telecoil can be used on a relatively low setting with that device; if the inductive field is comparatively weak, the sensitivity of the telecoil needs to be increased to obtain an adequate signal; however, if there is EMI from another source, undesired noise will also be picked up by the telecoil. For telecoil users, it is thus very desirable for the inductive field originating in the telephone to be strong so that the telecoil can be less sensitive to EMI from undesired sources that may exist either in the environment or in other parts of the telephone.

The SHHH survey of mobile phone use by people with hearing loss, conducted in September of 2002, showed that although most respondents had a telecoil in their hearing aid or CI, many could not use the telecoil with digital mobile phones (due either to increased interference or lack of an inductive field from the phone) and resorted to using the hearing aid in microphone mode or with neckloop accessories.

The ex parte letter from CTIA in late 2002 referenced this survey but incorrectly portrays the use of the microphone mode as the most "popular" (implying well-liked) way of using the phone when in fact, many users complained of frequent problems using the phone in microphone mode. In microphone mode, the hearing aid or CI usually also amplifies background noise indiscriminately, which may overpower the speech signal from the telephone. Ironically, the amplified background noise becomes louder for people with hearing loss than it is for people with normal hearing, but users of BTE (behind the ear) hearing devices are not able to block out noise by sealing the earpiece with the outer ear (doing this would prevent the microphone of the hearing device from picking up the speech signal). Many people with powerful telecoil-equipped hearing aids are able to use them very successfully and easily with HAC phones but are unable to discern speech on phones otherwise.

The Benefit of Removing the HAC Exemption for Wireless Telephones

Removing the exemption of wireless phones from the HAC Act would address multiple accessibility problems. It would improve the accessibility of wireless phones that are already free of interference but that do not provide a strong enough induction field. It would allow users of hearing aids and cochlear implants that are already shielded against radio frequency interference to use phones that might currently lack any inductive coupling at all. It would pave the way for engineers to work more comprehensively and consistently on problems of interference with telecoils, and introducing solutions that are readily achievable today.

Requiring even stronger inductive fields than that required by Part 68 would greatly improve the usability even of phones that have sources of strong interference in the phone that are separate from the audio components.

Expanding the HAC Act to include mobile phones is thus very important in improving access to all phones by people with hearing loss who are already able to use landline phones as a result of the HAC law.

Interference Issues

The primary reason many users of hearing aids or cochlear implants experience noise directly caused by digital radio frequency (RF) transmissions is the pulsing of the RF signal, which appears to induce continually varying current in the small wires of the HA or CI. One misconception we have seen is that only hearing aids with telecoils experience this problem; however, this is incorrect. The amplifiers in the affected HAs or CIs pick up and amplify the undesired transmissions regardless of whether a telecoil is present.

Many newer hearing aids are designed with increased immunity to RF energy by incorporating changes in circuit design or shielding, but users of telecoils in these hearing aids can nevertheless experience other forms of electromagnetic interference (EMI) that are still present in many digital mobile phones. Thus even users of hearing aids or CIs that are shielded against radio frequency interference can find that they are unable to use the telecoil of their hearing devices with many digital phones. Although some may be able to use the microphone of their HA or CI successfully with the phone if they cannot use the telecoil, they may have extreme difficulty using the phone in any situation with background noise. (This problem was noted by many respondents to the SHHH survey.) **Users with such difficulties will be unable to understand calls in urgent situations, including emergencies, if it is not possible for them to use the**

telecoil.

Types of Radiation

Wireless phones emit at least two kinds of radiation:

(A) The RF signal at 800 Mhz, 900 Mhz, 1900 Mhz – according to the digital transmission protocol used by the wireless service provider.

There is strong evidence that it is possible to reduce RF transmissions to a hearing aid by employing a directional antenna or RF shielding in the phone.

(B) Extraneous radiation from the wireless phone's battery, power supply components and wiring. In this paper, this kind of interference is called "Inductive EMI" but also falls within the category of non-RF interference. Telecoils are designed to receive all such signals **in the audio range** and to transmit them to the processor in the hearing aid. A telecoil is non-selective and cannot differentiate between unwanted noise and desired speech signals.

Inductive EMI/non-RF interference is generated by a continually changing or pulsating current anywhere in the phone. Two sources of varying current are identified and there may be more:

1. Activated components that cause the current from the battery to vary, regardless of whether the phone is engaged in a call. An example of this is the backlight for some displays. EMI/non-RF interference from the display is received by the telecoil and amplified by the hearing aid and in one instance was heard as a 700 Hz tone. (Some phones allow the backlight to be turned off permanently; some do not.)

2. Continually varying current caused by the RF transmitter, experienced only when the phone is engaged in a call. Unless preventive measures are taken, affected conductors, including the battery, radiate inductive EMI/non-RF interference. When phones operate in a time-sharing multiplex network, the RF transmitters turn on and off at the rate of multiplexing (often 50 Hz or 200 Hz depending on the type of network). The heavy current drawn by the RF transmitter causes an inductive EMI at the multiplexing rate, received by the telecoil and then amplified into a buzz by the hearing aid. (Shielding only HAs or CIs against RF emissions would do nothing to resolve the RF-caused EMI inside the phone.)

Suggested Technically Feasible Solutions

Below are suggestions to increase the usability of phones for users of hearing aids and cochlear implants. These suggestions would also be likely to expand the usability of digital wireless phones with other products.

(1) "Increase the strength of the radiated HAC field"

Explanation:

(i) Lift the wireless exemption from HAC. While some wireless phones already exhibit some degree of inductive coupling, by lifting the exemption, wireless phones would meet the standard specified by CFR 47, part 68. This would help to overcome interference generated by the phone and enable users with telecoil equipped hearing aids to use mobile phones.

(ii) If the strength specified in the Part 68 standard were increased for wireless phones the signal to noise ratio would increase since both telecoils and amplifiers of hearing aids/CIs could be set for minimum sensitivity when using a wireless phone. This would have the added benefit of allowing the telecoil to be less sensitive to EMI in the environment, a significant effect that would enhance the usability of mobile phones in different locations. (For example, trains can convey significant EMI that can make current inductive use of mobile phones impossible.)

(2) "Increase the size and effectiveness of the radiated HAC field with improved transmitting coils."

Explanation:

Instead of using the small speaker in mobile phones as a HAC radiating device, a coil specifically designed to transmit to the hearing aid telecoil would be more efficient in battery usage.

(3) "Provide a user option to select HAC mode."

Explanation:

A user option would conserve battery talk time by selecting the mode of output that the user needs.

Background information for (1), (2), and (3):

Technical Methods for Creating Inductive Coupling in Phones: before the HAC Act of 1989, many phones used a "piezoelectric" type of speaker in the handset. This type of speaker does not have a magnet or a coil of wire and it emitted very little radiation that a telecoil could receive. Before piezoelectric speakers were developed, speakers generally used a magnet and a coil of wire, with the coil attached to a diaphragm. The coil radiates the HAC signal as a by product of generating acoustic sound. Some designs had a stationary coil and a metal diaphragm that vibrated in response to the electrical signal.

When the HAC Act went into effect, phone manufacturers went back to some form of speaker that employed a coil. The speaker generates acoustic sound and the HAC signal, which a telecoil receives. It radiates the HAC speech signal as a byproduct since its primary function is to produce acoustic sound. It is not a strong radiator because its coil is surrounded and shielded by the magnet or other metal and thus cannot radiate well. A better solution is to use a separate coil and make it bigger. A larger coil would spread out the field and make the hearing aid telecoil easier to use since the user would not have to find a “sweet spot.”

The size and shape of the transmitting coil plus its impedance, and the amount of power applied to the coil will determine the strength of the field. A tradeoff to the strength would be reduced talk time of the battery. However, this can be overcome by a coil that is specifically designed to be a transmitting coil that would be more efficient in battery usage than one that can't radiate very well.

Piezo speakers are ideal for all types of phones because they need less power to operate, and are less expensive to manufacture. Their drawback is they do not generate the required HAC signal. Therefore one solution may be to use piezo speakers for acoustic sound and a separate transmitting coil for the HAC signal.

Method to Conserve Battery Life

Many mobile phones now have a "speaker-phone" type of function. These phones must have a robust battery to support a speaker-phone type of operation and as such they could easily generate a strong HAC signal. On such phones, the user would select either normal acoustic sound, speaker-phone acoustic sound, or telecoil only operation. Telecoil mode would not have significantly different power requirements from speaker-phone mode, and battery usage would be further enhanced by not generating acoustic sound when it is not needed, and not generating the HAC signal when it is not needed. Another benefit is privacy. If the user selects HAC only mode, then conversations would be more private.

(4) "Reduce interference by the physical design and shape of the phone"

Explanation:

Examples of this idea are the Samsung SCH3500 and the Samsung N200. These phones have a "flip-open" design whereby the only element that flips open and up is the speaker. This design places the speaker's coil next to the hearing aid telecoil and all other parts of the phone are down and away two to three inches. Additionally, the flip design would allow room for a transmitting coil that is as big as the flip part and shielding could be placed on the back side of the part that flips up away from the ear.) The flip part could also include a slide switch to choose between the speaker and the transmitting coil.

(5) Eliminate unnecessary interference from the display backlight and other hotspots.

Explanation:

Some components of the phone produce interference that is not related to the necessary RF transmission. These sources of interference can be eliminated by careful placement of components away from the telecoil, or shielding, or circuit design. For example, the LG TM-510 and the Samsung SCH-3500 both emit a 700 Hz tone when the display backlight is on. This tone has nothing to do with the phone's communication with the cell tower. Due to the loudness of the interference, the backlight has to be turned off in order to use the phone inductively (with a telecoil). Therefore phones need to be designed with the capability to turn off the back light.

(6) Design battery compartment and all associated battery supply conductors to cancel inductive EMI/non-RF interference.

Explanation:

Shielded cable, twisted pair cable, and transmission lines are designed to prevent unwanted radiation by cancellation. In effect, as one conductor is generating a positive radiation, its companion conductor is generating an equal but opposite negative radiation, so the two radiations cancel each other out. Therefore the noise would be reduced considerably, resulting in a better signal-to-noise ratio. Since the battery is almost as large as the phone, it is a very effective radiator of inductive EMI. Testing and experiments have shown that the battery compartment can be re-arranged to provide cancellation.

(7) Design shielding to reduce Inductive EMI/non RF interference and RF at the earpiece/speaker.

Explanation:

Different types of metal have to be used to shield each kind of radiation. Copper, brass, aluminum, and some other materials are effective at RF frequencies, and ferrous metals are effective at the lower audio frequencies that would otherwise be transmitted via induction. "Mu Metal" is commonly used by electronic industries to shield against Inductive EMI. Effective shielding reduces noise, resulting in a higher S/N ratio.

(8) Ensure audio components are free of EMI.

Filter capacitors can be used to ensure that the power to the audio components is free of the effects of EMI. Shielding must also be used to prevent alteration of the current by EMI after the current passes through the filter capacitor.